2010

Torres Strait reefs and carbonate production: a geospatial approach

Javier Xavier Leon Patino
University of Wollongong

TORRES STRAIT REEFS AND CARBONATE PRODUCTION: A GEOSPATIAL APPROACH

A thesis submitted in fulfilment of the requirements
for the award of the degree of

DOCTOR OF PHILOSOPHY

From

THE UNIVERSITY OF WOLLONGONG

By

JAVIER LEON

B.A. (Hons), Pontificia Universidad Católica, Perú
M.Sc. (Hons) University of Canterbury, New Zealand

SCHOOL OF EARTH AND ENVIRONMENTAL SCIENCES

March, 2010

"The Torres Straits are nearly thirty-four leagues wide; but they are obstructed by an innumerable quantity of islands, islets, breakers, and rocks, that make its navigation almost impracticable; so that Captain Nemo took all needful precautions to cross them. The Nautilus, floating betwixt wind and water, went at a moderate pace. Her screw, like a cetacean's tail, beat the waves slowly."

- Jules Verne, 20 000 leagues under the sea (p.94, 1963, Airmont:NY)

Certification

I, **Javier León**, declare that this thesis, submitted in fulfilment of the requirements for the award of **Doctor of Philosophy**, **in the School of Earth and Environmental Sciences, University of Wollongong**, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Dedication

This is dedicated to my grandparents from whom I have learnt that the key to enjoying the journey of life resides in keeping things simple, doing what you like most and, of course, having a good company by your side.

Abstract

Coral reefs are particularly valuable marine ecosystems in terms of biodiversity and socio-economic factors. They are also some of the most vulnerable and threatened of global ecosystems, particularly in view of unprecedented anthropogenic-driven disturbances. Understanding coral reef evolution is not straightforward, as these are complex systems where biological, physical and chemical processes continually interact over a range of spatial and temporal scales. The study of coral reef dynamics at geomorphological scales is very suitable for management as it bridges the temporal and spatial gap between long-term geological and short-term ecological processes. Mapping the geomorphology of coral reefs has provided key information to scientists and managers about the distribution and extent of reef landforms giving insights into calcium carbonate ($CaCO_3$) production and reef growth.

Coral reef coasts present a series of challenges to scientists and managers because they tend to be largely inaccessible, both in that they are isolated and because they are underwater or in intertidal settings where fieldwork is weather and tide dependent. In addition, field surveying rapidly becomes cost-prohibitive as the area of study increases or higher-frequency surveys are needed. Remote sensed data, both from passive and active sensors, together with geospatial analysis techniques, allow addressing the challenges of studying such unique environments at multiple scales and significantly improve the science needed for a sound and efficient management.

Scaling up coral reef $CaCO_3$ production from community metabolism values to regional estimates has been undertaken using remote sensing and geospatial techniques. This approach, although being of great significance for science and management implications, considerably lags behind ecological models of primary production used in terrestrial applications. Furthermore, previous regional studies are geographically constrained and have been based mostly on generalized published metabolic values and coarse mapping.

The research which is the focus of this thesis aims to bridge the gap between detailed and regional geomorphological studies on coral reefs by scaling up $CaCO_3$ production across the Torres Strait region. In order to do so, two reefs in central Torres Strait

were selected, namely Sue (Warraber) and Bet (Burrar) reef platforms and detailed investigations about morphology and carbonate production were undertaken. Insights from the local case studies were further used to extrapolate carbonate production estimates across the region based on a reliable geomorphological classification dataset.

The case study reefs were selected as they represent different stages of geomorphological evolution. Sue platform is an emergent reef extending for approximately 12.6 km^2, while Bet, immediately to the north of Sue, is a larger reef extending for 27 km^2 with a mostly submerged lagoon and very shallow intertidal reef flat. A combination of data collection methods, including multibeam echosounding, RTK-GPS survey and optical remote-sensing derived bathymetry were used to analyse the complex terrain of both reefs. Previous ecological surveys combined with geomorphological mapping were used to scale up $CaCO_3$ production for the complete platforms, including the productive forereef. The $CaCO_3$ production for Sue was estimated to be 19,432 t $CaCO_3$ $year^{-1}$, averaging a production rate of 1.81 $CaCO_3$ m^{-2} yr^{-1}. The estimate for Bet platform added to an average 88,167 t $CaCO^3$ $year^{-1}$, yielding a rate of 3.1 kg $CaCO_3$ m^{-2} yr^{-1}.

Despite being a northern extension of the Great Barrier Reef (GBR), the geomorphology of coral reefs in Torres Strait remains unexamined at a detailed level. Innovative classification and spatial analysis techniques were used to accurately map the intra-reef geomorphology of reefs, which was used as a basis to extrapolate $CaCO_3$ production and derive a regional carbonate production for Torres Strait. A maximum total of 9.6 million tonnes $CaCO_3$ yr^{-1} were estimated for the 2,500 km^2 analysed region, averaging a value of 4.1 kg $CaCO_3$ m^{-2} yr^{-1}, almost twice the 2.4 kg $CaCO_3$ m^{-2} yr^{-1} productivity rate previously estimated for the GBR.

Overall, the geospatial framework adopted in this study effectively complemented the regional scaling up of $CaCO_3$ production for Torres Strait. Results improve and advance our knowledge of coral reef dynamics at geomorphological scales, which are very relevant for management and adaptation, particularly in regards to the future prospect of corals in a rapid changing climate context.

Table of Contents

List of Figures

List of Tables

Acknowledgements

This thesis is the product of almost four years of research and many have participated or been involved to some degree throughout the process. Thanks to you all.

I would specially like to thank Professor Colin Woodroffe, my supervisor, my mentor.

Funding for this PhD was granted by an International Postgraduate Research Scholarship (IPRS) from the University of Wollongong.

Support from the School of Earth and Environmental Sciences staff is greatly appreciated, particularly from former Head of School Lesley Head, Wendy and Denise, and by Heidi Brown and John Marthic from the Spatial Analysis Lab. Thanks also to Marji Puotinen and Laurie Chisholm for giving me with the opportunity to teach and try helping others avoid the sufferings of using GIS and remote sensing (!).

Fieldwork was possible thanks to the island councils on those islands visited in Torres Strait and Kevin Parnell and Scott Smithers from James Cook University (extra thanks for helpful insights, data and those coral trouts and lobsters!). Additional data was also provided by Tom Taranto and Tim Skewes from CSIRO. Special thanks to both Deirdre Hart and Ong Samosorn for the willingness to help, so much feedback and helping with the analysis of datasets.

Thanks to all the postgrads for their support and friendship. Good times and good vibes are essential when pushing through the PhD process.

To my family, and my extended family, thank you always for the unconditional love.

And to Denise, my girl. This is for us. You are my motivation. You are my company in this awesome journey.